Part 25—Airworthiness Standards: Transport Category Airplanes

This change incorporates two amendments:

Amendment 25–85, Revision of Authority Citations, effective December 28, 1995; and

Amendment 25–86, Revised Discrete Gust Load Design Requirements, effective March 11, 1996.

Bold brackets enclose the most recently changed and added material. The amendment number and effective date of the new material appear in bold brackets at the end of each affected section.

Page Control Chart

Remove Pages	Dated	Insert Pages	Dated
		P–571 through P–575	Ch. 7
Subpart C	Ch. 3	Subpart C	Ch. 7
Subpart G	—	Subpart G	Ch. 7

Suggest filing this transmittal at the beginning of the FAR. It will provide a method for determining that all changes have been received as listed in the current edition of AC 00–44, Status of Federal Aviation Regulations, and a check for determining if the FAR contains the proper pages.

authority upon the Federal Aviation Administration were recodified into positive law. This document updates the authority citations listed in the Code of Federal Regulations to reference the current law.

DATES: This final rule is effective December 28, 1995. Comments on this final rule must be received by March 1, 1996.

FOR FURTHER INFORMATION CONTACT: Karen Petronis, Office of the Chief Counsel, Regulations Division (AGC–210), Federal Aviation Administration, 800 Independence Ave., SW., Washington, DC 20591; telephone (202) 267–3073.

SUPPLEMENTARY INFORMATION: In July 1994, the Federal Aviation Act of 1958 and numerous other pieces of legislation affecting transportation in general were recodified. The statutory material became ''positive law'' and was recodified at 49 U.S.C. 1101 *et seq.*

The Federal Aviation Administration is amending the authority citations for its regulations in Chapter I of 14 CFR to reflect the recodification of its statutory authority. No substantive change was intended to any statutory authority by the recodification, and no substantive change is introduced to any regulation by this change.

Although this action is in the form of a final rule and was not preceded by notice and an opportunity for public comment, comments are invited on this action. Interested persons are invited to comment by submitting such written data, views, or arguments as they may desire by March 1, 1996. Comments should identify the rules docket number (Docket No. 28417) and be submitted to the address specified under the caption ''FOR FURTHER INFORMATION CONTACT.''

Because of the editorial nature of this change, it has been determined that prior notice is unnecessary under the Administrative Procedure Act. It has also been determined that this final rule is not a ''significant regulatory action'' under Executive Order 12866, nor is it a significant action under DOT regulatory policies and procedures (44 FR 11034, February 26, 1979). Further, the editorial nature of this change has no known or anticipated economic impact; accordingly, no regulatory analysis has been prepared.

Adoption of the Amendment

In consideration of the forgoing, the Federal Aviation Administration amends 14 CFR Chapter I effective December 28, 1995.

The authority citation for part 25 is revised to read as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701–44702, 44704.

Amendment 25–86

Revised Discrete Gust Load Design Requirements

Adopted: February 2, 1996 **Effective: March 11, 1996**

(Published in 61 FR 5218, February 9, 1996)

SUMMARY: This amendment revises the gust load design requirements for transport category airplanes. This amendment replaces the current discrete gust requirement with a new requirement for a discrete tuned gust; modifies the method of establishing the design airspeed for maximum gust intensity; and provides for an operational rough air speed. These changes are made in order to provide a more rational basis of accounting for the aerodynamic and structural dynamic characteristics of the airplane. These

The National Advisory Committee for Aeronautics (NACA), the predecessor of the National Aeronautics and Space Administration (NASA), began an inflight gust measurement program in 1933 to assist in the refinement of gust load design criteria. Using unsophisticated analog equipment, that program resulted in the development of the improved design requirements for gust loads that were issued in part 04 of the Civil Aeronautics Regulations (CAR) in the 1940's. The corresponding Civil Aeronautics Manual (CAM) 04 provided a simplified formula from which to derive the design gust loads from the specified design gust velocities. These criteria were based on an analytical encounter of the airplane with a discrete ramp-shaped gust with a gradient distance (the distance necessary for the gust to build to a peak) of 10 times the mean chord length of the airplane wing. An alleviation factor, calculated from wing loading, was provided in order to account for the relieving effects of rigid body motion of the airplane as it penetrated the gust. With the development of the VGH (velocity, load factor, height) recorder in 1946, NASA began collecting a large quantity of gust load data on many types of aircraft in airline service. Although that program was terminated for transport airline operations in 1971, the data provided additional insight into the nature of gusts in the atmosphere, and resulted in significant changes to the gust load design requirements. The evolution of the discrete gust design criteria from part 04 through part 4b of the CAR to current part 25 of Title 14 of the Code of Federal Regulations (CFR) (which contains the design requirements for transport category airplanes) resulted in the establishment of a prescribed gust shape with a specific gust gradient distance and increased peak gust design velocities. The prescribed shape was a "one-minus-cosine" gust shape with a specified gust gradient distance of 12.5 times the mean chord length of the airplane wing. The gust gradient distance, for that particular shape, was equal to one-half the total gust length. A simplified analytical method similar to the methodology of CAM 04 was provided along with an improved alleviation factor that accounted for unsteady aerodynamic forces, gust shape, and the airplane rigid body vertical response.

The increasing speed, size, and structural flexibility of transport airplanes resulted in the need to consider not only the rigid body response of the airplane, but also structural dynamic response and the effects of structural deformation on the aerodynamic parameters. Early attempts to account for structural flexibility led to a "tuned" gust approach in which the analysis assumed a flexible airplane encountering gusts with various gradient distances in order to find the most critical gust gradient distance for use in design for each major component. A tuned discrete gust approach became a requirement for compliance with the British Civil Airworthiness Requirements.

Another method of accounting for the structural dynamic effects of the airplane involved the power spectral density (PSD) analysis technique which accounted for the statistical distribution of gusts in continuous turbulence in conjunction with the aeroelastic and structural dynamic characteristics of the airplane. In the 1960's, the Federal Aviation Administration (FAA) awarded study contracts to Boeing and Lockheed for the purpose of assisting the FAA in developing the PSD gust methodology into continuous gust design criteria with analytical procedures. The final PSD continuous turbulence criteria were based on those studies and were codified in appendix G to part 25 in 1980.

Recognizing that the nature of gusts was not completely defined, and that individual discrete gusts might exist outside the normal statistical distribution of gusts in continuous turbulence, the FAA retained the existing criteria for discrete gusts in addition to the new requirement for continuous turbulence. The current discrete gust criteria in subpart C of part 25 require the loads to be analytically developed assuming the airplane encounters a gust with a fixed gradient distance of 12.5 mean chord lengths. For application of the current criteria, it is generally assumed that the airplane is rigid in determining the dynamic response to the gust while the effects of wing elastic deflection on wing static lift parameters are normally taken into account. The minimum value of the airplane design speed for maximum gust intensity, V_B, is also established from the discrete gust criteria.

Recent flight measurement efforts by FAA and NASA have been aimed at utilizing measurements from the digital flight data recorders (DFDR) to derive gust load design information for airline transport airplanes. The Civil Aviation Authority (CAA) of the United Kingdom has also been conducting a comprehensive DFDR gust measurement program for transport airplanes in airline service. The program, called

In 1992, the harmonization effort was undertaken by the Aviation Regulatory Advisory Committee (ARAC). A working group of industry and government structural loads specialists of Europe, the United States, and Canada was chartered by notice in the *Federal Register* (58 FR 13819, March 15, 1993) to harmonize certain specific sections of part 25, including the requirements related to discrete gusts. The harmonization task concerning discrete gusts was completed by the working group and recommendations were submitted to FAA by letter dated October 15, 1993. The FAA concurred with the recommendations and proposed them in Notice of Proposed Rulemaking (NPRM) No. 94–29 which was published in the *Federal Register* on September 16, 1994, (59 FR 47756).

Discussion of Comments

Comments were received from domestic and foreign aviation manufacturers and foreign airworthiness authorities. The majority of the commenters agreed with the proposal and recommended its adoption. However, some commenters disagreed substantially with the proposal while providing alternative proposals that appeared to merit further consideration by the Aviation Rulemaking Advisory Committee. Therefore the FAA tasked the ARAC Loads and Dynamics Working Group by notice in the *Federal Register* (60 FR 18874, April 13, 1995) to consider the comments and provide recommendations for the disposition of the comments along with any recommendations for changes to the proposal. The disposition of comments that follows is based on the recommendation submitted to the FAA by ARAC on July 14, 1995.

One commenter suggests that the new method for calculating the minimum V_B results in lower values at altitude than the current method provided in the Joint Aviation Requirements (JAR) and could provide unrealistic margins above the stalling speed. The FAA disagrees. The commenter provides no data or other information that shows the new V_B calculations to be unrealistic. The new method for calculating the minimum V_B is approximately the same as in the current FAR and JAR; the main difference being that revised gust speeds are used in the calculation. These gust speeds are based on actual measurements in aircraft operation and are considered to result in a realistic and conservative V_B speed, even if it is somewhat lower than the current requirements at some altitudes. In addition, a new operational rough air speed, V_{RA}, is provided in order to ensure adequate stall margins while operating in rough air. As part of the effort to harmonize the airworthiness requirements, the JAA is also considering adopting this method of calculating the minimum V_B speeds. This commenter, along with several others, also points out an error in the formula for the design speed for maximum gust intensity, V_B, in § 25.335(d) and this error has been corrected.

One commenter suggests that the proposed tuned gust criteria do not fully account for the dynamic response of the airplane and therefore could produce unconservative results and seriously underpredict the gust design loads. The commenter suggests that the proposal be replaced by an entirely new method of accounting for discrete gusts. This method is known in the industry as the statistical discrete gust method (SDG). In response to the task defined in the *Federal Register*, the ARAC Loads and Dynamics Working Group considered the commenters comments and the alternate proposal in considerable detail. It is recognized by the working group that the current proposed tuned gust criteria have some limitations and that the suggested SDG method may have some promising applications for predicting gust loads. However, the SDG method is in a developmental stage, and there is currently no established industry process for using this method in predicting gust design loads. The FAA will retain the commenters proposal for possible consideration in future rulemaking actions. In response to the commenters specific concerns, neither ARAC nor the FAA agree that the tuned gust method will result in unconservative design loads. In addition, for the extreme gust gradient distances where the commenter questions the adequacy of the tuned gust method to fully account for dynamic response, the FAA considers that the additional continuous gust criteria of § 25.341(b) will compensate for any possible deficiencies. The commenter provides some comparisons of loads produced by the SDG method with the results of the proposed tuned gust method. These results show no significant differences in overall load levels when all factors are considered, and in some cases the SDG method actually provided lower design loads. Therefore, except for an editorial correction to the mathematical equation noted above, the amendment is adopted as proposed.

and is not "significant" as defined in Executive Order 12866; (2) is not "significant" as defined in DOT's Policies and Procedures; (3) will not have a significant impact on a substantial number of small entities; and (4) will not constitute a barrier to international trade. These analyses, available in the docket, are summarized below.

Costs and Benefits

The changes will have economic consequences. The costs will be the incremental costs of meeting the tuned discrete gust requirements rather than the current static discrete gust requirements. The benefits will be the cost savings from not meeting two different sets of discrete gust requirements, i.e., the requirements in the current FAR and the requirements in the JAR. In order to sell their transport category airplanes in a global marketplace, manufacturers usually certify their products under both sets of regulations.

Industry sources provided information on the additional costs and cost savings that would result from the rule. Based on this information, a range of representative certification costs and savings are shown below. The costs and savings per certification are those related to meeting discrete gust load requirements, including related provisions of the final rule.

PER CERTIFICATION COSTS AND SAVINGS ASSOCIATED WITH REVISED DISCRETE GUST LOAD REQUIREMENTS

(in thousands of dollars)

Current FAA certification requirement costs	\$29–\$115
Current JAA certification requirement costs	\$70–\$145
Current joint certification requirement costs	\$100–\$150
Revised FAA certification requirement costs	\$70–\$145
Revised joint certification requirement costs	\$70–\$145
Savings (current joint certification costs minus revised joint certification costs)	\$5–\$30

The costs and cost savings of specific certifications may vary from these estimates. In all cases where a manufacturer seeks both FAA and JAA certification, however, the cost savings realized through harmonized requirements will outweigh the expected incremental costs of the rule. The FAA did not receive comments concerning this quantification of costs during the comment period; therefore, the FAA holds that these are representative costs and savings.

Regulatory Flexibility Determination

The Regulatory Flexibility Act of 1980 (RFA) was enacted by Congress to ensure that small entities are not unnecessarily and disproportionately burdened by Federal regulations. The RFA requires agencies to review rules which may have "a significant economic impact on a substantial number of small entities." FAA Order 2100.14A outlines FAA's procedures and criteria for implementing the RFA.

An aircraft manufacturer must employ 75 or fewer employees to be designated as a "small" entity. A substantial number of small entities is defined as a number that is 11 or more and which is more than one-third of the small entities subject to a proposed or final rule. None of the manufacturers of transport category airplanes qualify as small entities under this definition. Therefore, the final rule will not have a significant economic impact on a substantial number of small entities.

International Trade Impact Assessment

The rule will not constitute a barrier to international trade, including the export of American goods and services to foreign countries and the import of foreign goods and services into the United States. The discrete gust load requirements in this rule will harmonize with those of the JAA and will, in fact, lessen the restraints on trade.

cost, the FAA has determined that this regulation would not be significant under Executive Order 12866. Because this is an issue that has not promoted a great deal of public concern, the FAA has determined that this action is not significant under DOT Regulatory Policies and Procedures (44 FR 11034; February 25, 1979). In addition, since there are no small entities affected by this rulemaking, the FAA certifies that the rule would not have a significant economic impact, positive or negative, on a substantial number of small entities under the criteria of the Regulatory Flexibility Act, since none would be affected. A copy of the regulatory evaluation prepared for this project may be examined in the Rules Docket (Docket No. 27902) or obtained from the person identified under the caption ''FOR FURTHER INFORMATION CONTACT.''

The Amendments

In consideration of the foregoing, the Federal Aviation Administration (FAA) amends 14 CFR part 25 of the Federal Aviation Regulations (FAR) effective March 11, 1996.

The authority citation for part 25 continues to read as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701, 44702 and 44704.

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§ 25.301 Loads.

(a) Strength requirements are specified in terms of limit loads (the maximum loads to be expected in service) and ultimate loads (limit loads multiplied by prescribed factors of safety). Unless otherwise provided, prescribed loads are limit loads.

(b) Unless otherwise provided, the specified air, ground, and water loads must be placed in equilibrium with inertia forces, considering each item of mass in the airplane. These loads must be distributed to conservatively approximate or closely represent actual conditions. Methods used to determine load intensities and distribution must be validated by flight load measurement unless the methods used for determining those loading conditions are shown to be reliable.

(c) If deflections under load would significantly change the distribution of external or internal loads, this redistribution must be taken into account.

(Amdt. 25–23, Eff. 5/8/70)

§ 25.303 Factor of safety.

Unless otherwise specified, a factor of safety of 1.5 must be applied to the prescribed limit load which are considered external loads on the structure. When a loading condition is prescribed in terms of ultimate loads, a factor of safety need not be applied unless otherwise specified.

(Amdt. 25–23, Eff. 5/8/70)

§ 25.305 Strength and deformation.

(a) The structure must be able to support limit loads without any detrimental permanent deformation. At any load up to limit loads, the deformation may not interfere with safe operation.

(b) The structure must be able to support ultimate loads without failure for at least 3 seconds. However, when proof of strength is shown by dynamic tests simulating actual load conditions, the 3-second limit does not apply. Static tests conducted to ultimate load must include the ultimate deflections and ultimate deformation induced by the loading. When with the ultimate load strength requirements, it must be shown that—

(1) The effects of deformation are not significant;

(2) The deformations involved are fully accounted for in the analysis; or

(3) The methods and assumptions used are sufficient to cover the effects of these deformations.

(c) Where structural flexibility is such that any rate of load application likely to occur in the operating conditions might produce transient stresses appreciably higher than those corresponding to static loads, the effects of this rate of application must be considered.

(d) [Reserved]

(e) The airplane must be designed to withstand any vibration and buffeting that might occur in any likely operating condition up to V_D/M_D, including stall and probable inadvertent excursions beyond the boundaries of the buffet onset envelope. This must be shown by analysis, flight tests, or other tests found necessary by the Administrator.

(f) Unless shown to be extremely improbable, the airplane must be designed to withstand any forced structural vibration resulting from any failure, malfunction or adverse condition in the flight control system. These must be considered limit loads and must be investigated at airspeeds up to V_C/M_C.

(Amdt. 25–23, Eff. 5/8/70); (Amdt. 25–54, Eff. 10/14/80); (Amdt. 25–77, Eff. 7/29/92); [(Amdt. 25–86, Eff. 3/11/96)]

§ 25.307 Proof of structure.

(a) Compliance with the strength and deformation requirements of this subpart must be shown for each critical loading condition. Structural analysis may be used only if the structure conforms to that for which experience has shown this method to be reliable. The Administrator may require ultimate load tests in cases where limit load tests may be inadequate.

(b) [Reserved]

of the load through alternate load paths.

(Amdt. 25–23, Eff. 5/8/70); (Amdt. 25–54, Eff. 10/14/80); (Amdt. 25–72, Eff. 8/20/90)

FLIGHT LOADS

§ 25.321 General.

(a) Flight load factors represent the ratio of the aerodynamic force component (acting normal to the assumed longitudinal axis of the airplane) to the weight of the airplane. A positive load factor is one in which the aerodynamic force acts upward with respect to the airplane.

(b) Considering compressibility effects at each speed, compliance with the flight load requirements of this subpart must be shown—

(1) At each critical altitude within the range of altitudes selected by the applicant;

(2) At each weight from the design minimum weight to the design maximum weight appropriate to each particular flight load condition; and

(3) For each required altitude and weight, for any practicable distribution of disposable load within the operating limitations recorded in the Airplane Flight Manual.

[(c) Enough points on and within the boundaries of the design envelope must be investigated to ensure that the maximum load for each part of the airplane structure is obtained.

[(d) The significant forces acting on the airplane must be placed in equilibrium in a rational or conservative manner. The linear inertia forces must be considered in equilibrium with the thrust and all aerodynamic loads, while the angular (pitching) inertia forces must be considered in equilibrium with thrust and all aerodynamic moments, including moments due to loads on components such as tail surfaces and nacelles. Critical thrust values in the range from zero to maximum continuous thrust must be considered.]

(Amdt. 25–23, Eff. 5/8/70); [(Amdt. 25–86, Eff. 3/11/96)]

([1]) [Where sudden displacement of a control is specified, the assumed rate of control surface displacement may not be less than the rate that could be applied by the pilot through the control system.

([2]) [In determining elevator angles and chordwise load distribution in the maneuvering conditions of paragraphs (b) and (c) of this section, the effect of corresponding pitching velocities must be taken into account. The in-trim and out-of-trim flight conditions specified in § 25.255 must be considered.]

(b) *Maneuvering balanced conditions.* Assuming the airplane to be in equilibrium with zero pitching acceleration, the maneuvering conditions A through I on the maneuvering envelope in § 25.333(b) must be investigated.

(c) *Maneuvering pitching conditions.* The following conditions involving pitching acceleration must be investigated:

(1) *Maximum elevator displacement at V_A.* The airplane is assumed to be flying in steady level flight (point A_1, § 25.333(b)) and, except as limited by pilot effort in accordance with § 25.397(b), the pitching control is suddenly moved to obtain extreme positive pitching acceleration (nose up). The dynamic response or, at the option of the applicant, the transient rigid body response of the airplane, must be taken into account in determining the tail load. Airplane loads which occur subsequent to the normal acceleration at the center of gravity exceeding the maximum positive limit maneuvering load factor, n, need not be considered.

(2) *Specified control displacement.* A checked maneuver, based on a rational pitching control motion vs. time profile, must be established in which the design limit load factor specified in § 25.337 will not be exceeded. Unless lesser values cannot be exceeded, the airplane response must result in pitching accelerations not less than the following:

(i) A positive pitching acceleration (nose up) is assumed to be reached concurrently with the airplane load factor of 1.0 (points A^1 to and V is the airplane equivalent speed in knots.

(ii) A negative pitching acceleration (nose down) is assumed to be reached concurrently with the positive maneuvering load factor (points A_2 to D_2, § 25.333(b)). This negative pitching acceleration must be equal to at least

$$\frac{-26n}{V} \quad (n-1.5), \text{ (Radians/sec.}^2\text{)}$$

where—

n is the positive load factor at the speed under consideration; and V is the airplane equivalent speed in knots.

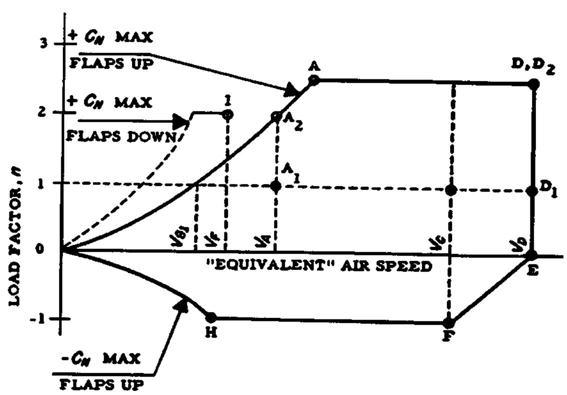
(d) [Removed]

(Amdt. 25–23, Eff. 5/8/70); (Amdt. 25–46, Eff. 12/1/78); (Amdt. 25–72, Eff. 8/20/90); [(Amdt. 25–86, Eff. 3/11/96)]

§ 25.333 Flight [maneuvering] envelope.

(a) *General.* [The strength requirements must be met at each combination of airspeed and load factor on and within the boundaries of the representative maneuvering envelope (V-n diagram) of paragraph (b) of this section. This envelope must also be used in determining the airplane structural operating limitations as specified in § 25.1501.]

(b) *Maneuvering envelope.*



(c) [Removed]

[(Amdt. 25–86, Eff. 3/11/96)]

speed increases likely to occur as a result of severe atmospheric turbulence.

(2) In the absence of a rational investigation substantiating the use of other values, V_C may not be less than V_B+43 knots. However, it need not exceed the maximum speed in level flight at maximum continuous power for the corresponding altitude.

(3) At altitudes where V_D is limited by Mach number, V_C may be limited to a selected Mach number.

(b) *Design dive speed, V_D.* V_D must be selected so that V_C/M_C is not greater than 0.8 V_D/M_D, or so that the minimum speed margin between V_C/M_C *and* V_D/M_D is the greater of the following values:

(1) From an initial condition of stabilized flight at V_C/M_C, the airplane is upset, flown for 20 seconds along a flight path 7.5° below the initial path, and then pulled up at a load factor of 1.5g (0.5g acceleration increment). The speed increase occurring in this maneuver may be calculated if reliable or conservative aerodynamic data is issued. Power as specified in § 25.175(b)(1)(iv) is assumed until the pullup is initiated, at which time power reduction and the use of pilot controlled drag devices may be assumed;

(2) The minimum speed margin must be enough to provide for atmospheric variations (such as horizontal gusts, and penetration of jet streams and cold fronts) and for instrument errors and airframe production variations. These factors may be considered on a probability basis. However, the margin at altitude where M_C is limited by compressibility effects may not be less than 0.05M.

(c) *Design maneuvering speed, V_A.* For V_A, the following apply:

(1) V_A may not be less than $V_{S1}\sqrt{n}$ where—

(i) n is the limit positive maneuvering load factor at V_C; and

(ii) V_{S1} is the stalling speed with flaps retracted.

(2) V_A and V_S must be evaluated at the design weight and altitude under consideration.

where—

V_{S1} = the 1-g stalling speed based on C_{NAmax} with the flaps retracted at the particular weight under consideration;

V_c = design cruise speed (knots equivalent airspeed);

U_{ref} = the reference gust velocity (feet per second equivalent airspeed) from § 25.341(a)(5)(i);

w = average wing loading (pounds per square foot) at the particular weight under consideration.

$$K_g = \frac{.88\mu}{5.3+\mu}$$

$$\mu = \frac{2w}{\rho cag}$$

ρ = density of air (slugs/ft³);

c = mean geometric chord of the wing (feet);

g = acceleration due to gravity (ft/sec²);

a = slope of the airplane normal force coefficient curve, C_{NA} per radian;

(2) At altitudes where V_C is limited by Mach number—

(i) V_B may be chosen to provide an optimum margin between low and high speed buffet boundaries; and,

(ii) V_B need not be greater than V_C.]

(e) *Design flap speeds,* V_F. For V_F, the following apply:

(1) The design flap speed for each flap position (established in accordance with § 25.697(a)) must be sufficiently greater than the operating speed recommended for the corresponding stage of flight (including balked landings) to allow for probable variations in control of airspeed and for transition from one flap position to another.

(2) If an automatic flap positioning or load limiting device is used, the speeds and corresponding flap positions programmed or allowed by the device may be used.

(3) V_F may not be less than—

(i) 1.6 V_{S1}, with the flaps in takeoff position at maximum takeoff weight;

(ii) 1.8 V_{S1}, with the flaps in approach position at maximum landing weight; and

(iii) 1.8 V_{S0} with the flaps in landing position at maximum landing weight.

grammed or allowed by the automatic means must be used for design.

(Amdt. 25–23, Eff. 5/8/70); [(Amdt. 25–86, Eff. 3/11/96)]

§ 25.337 Limit maneuvering load factors.

(a) Except where limited by maximum (static) lift coefficients, the airplane is assumed to be subjected to symmetrical maneuvers resulting in the limit maneuvering load factors prescribed in this section. Pitching velocities appropriate to the corresponding pull-up and steady turn maneuvers must be taken into account.

(b) The positive limit maneuvering load factor "n" for any speed up to V_N may not be less than

$$2.1 + \left(\frac{24{,}000}{W+10{,}000} \right)$$

except that "n" may not be less than 2.5 and need not be greater than 3.8—where "W" is the design maximum takeoff weight.

(c) The negative limit maneuvering load factor—

(1) May not be less than −1.0 at speeds up to V_C; and

(2) Must vary linearly with speed from the value at V_C to zero at V_D.

(d) Maneuvering load factors lower than those specified in this section may be used if the airplane has design features that make it impossible to exceed these values in flight.

(Amdt. 25–23, Eff. 5/8/70)

§ 25.341 Gust [and turbulence] loads.

[(a) *Discrete Gust Design Criteria.* The airplane is assumed to be subjected to symmetrical vertical and lateral gusts in level flight. Limit gust loads must be determined in accordance with the following provisions:

[(1) Loads on each part of the structure must be determined by dynamic analysis. The analysis must take into account unsteady aerodynamic where—

s = distance penetrated into the gust (feet);

U_{ds} = the design gust velocity in equivalent airspeed specified in paragraph (a)(4) of this section; and

H = the gust gradient which is the distance (feet) parallel to the airplane's flight path for the gust to reach its peak velocity.

[(3) A sufficient number of gust gradient distances in the range 30 feet to 350 feet must be investigated to find the critical response for each load quantity.

[(4) The design gust velocity must be:

$$U_{ds} = U_{ref} F_g \left(\frac{H}{350} \right)^{1/6}$$

where—

U_{ref} = the reference gust velocity in equivalent airspeed defined in paragraph (a)(5) of this section.

F_g = the flight profile alleviation factor defined in paragraph (a)(6) of this section.

[(5) The following reference gust velocities apply:

(i) At the airplane design speed V_C: Positive and negative gusts with reference gust velocities of 56.0 ft/sec EAS must be considered at sea level. The reference gust velocity may be reduced linearly from 56.0 ft/sec EAS at sea level to 44.0 ft/sec EAS at 15000 feet. The reference gust velocity may be further reduced linearly from 44.0 ft/sec EAS at 15000 feet to 26.0 ft/sec EAS at 50000 feet.

(ii) At the airplane design speed V_D: The reference gust velocity must be 0.5 times the value obtained under § 25.341(a)(5)(i).

[(6) The flight profile alleviation factor, F_g, must be increased linearly from the sea level value to a value of 1.0 at the maximum operating altitude defined in § 25.1527. At sea level, the flight profile alleviation factor is determined by the following equation:

$$F_g = 0.5\left(F_{gz} + F_{gm}\right)$$

where—

Maximum Take-off Weight

$$R_2 = \frac{\text{Maximum Zero Fuel Weight}}{\text{Maximum Take-off Weight}};$$

Z_{mo} = Maximum operating altitude defined in § 25.1527.

[(7) When a stability augmentation system is included in the analysis, the effect of any significant system nonlinearities should be accounted for when deriving limit loads from limit gust conditions.

[(b) *Continuous Gust Design Criteria.* The dynamic response of the airplane to vertical and lateral continuous turbulence must be taken into account. The continuous gust design criteria of appendix G of this part must be used to establish the dynamic response unless more rational criteria are shown.]

(Amdt. 25–72, Eff. 8/20/90); [(Amdt. 25–86, Eff. 3/11/96)]

§ 25.343 Design fuel and oil loads.

(a) The disposable load combinations must include each fuel and oil load in the range from zero fuel and oil to the selected maximum fuel and oil load. A structural reserve fuel condition, not exceeding 45 minutes of fuel under the operating conditions in § 25.1001(e) and (f), as applicable, may be selected.

(b) If a structural reserve fuel condition is selected, it must be used as the minimum fuel weight condition for showing compliance with the flight load requirements as prescribed in this subpart. In addition—

(1) The structure must be designed for a condition of zero fuel and oil in the wing at limit loads corresponding to—

(i) A maneuvering load factor of +2.25; and

(ii) [The gust conditions of § 25.341(a) but assuming 85% of the design velocities prescribed in § 25.341(a)(4).]

§ 25.345 High lift devices.

(a) [If wing flaps are to be used during takeoff, approach, or landing, at the design flap speeds established for these stages of flight under § 25.335(e) and with the wing flaps in the corresponding positions, the airplane is assumed to be subjected to symmetrical maneuvers and gusts. The resulting limit loads must correspond to the conditions determined as follows:

(1) [Maneuvering to a positive limit load factor of 2.0; and

(2) [Positive and negative gusts of 25 ft/sec EAS acting normal to the flight path in level flight. Gust loads resulting on each part of the structure must be determined by rational analysis. The analysis must take into account the unsteady aerodynamic characteristics and rigid body motions of the aircraft. The shape of the gust must be as described in § 25.341(a)(2) except that—

U_{ds} = 25 ft/sec EAS;

H = 12.5 c; and

c = mean geometric chord of the wing (feet).]

(b) The airplane must be designed for the conditions prescribed in paragraph (a) of this section, except that the airplane load factor need not exceed 1.0, taking into account, as separate conditions, the effects of—

(1) Propeller slipstream corresponding to maximum continuous power at the design flap speeds V_F, and with takeoff power at not less than 1.4 times the stalling speed for the particular flap position and associated maximum weight; and

(2) A head-on gust of 25 feet per second velocity (EAS).

(c) [If flaps or other high lift devices are to be used in en route conditions, and with flaps in the appropriate position at speeds up to the flap design speed chosen for these conditions, the airplane is assumed to be subjected to symmetrical maneuvers and gusts within the range determined by—

(1) [Maneuvering to a positive limit load factor as prescribed in § 25.337(b); and

§ 25.349 Rolling conditions.

[The airplane must be designed for loads resulting from the rolling conditions specified in paragraphs (a) and (b) of this section. Unbalanced aerodynamic moments about the center of gravity must be reacted in a rational or conservative manner, considering the principal masses furnishing the reaching inertia forces.]

(a) *Maneuvering.* The following conditions, speeds, and aileron deflections (except as the deflections may be limited by pilot effort) must be considered in combination with an airplane load factor of zero and of two-thirds of the positive maneuvering factor used in design. In determining the required aileron deflections, the torsional flexibility of the wing must be considered in accordance with § 25.301(b):

(1) Conditions corresponding to steady rolling velocities must be investigated. In addition, conditions corresponding to maximum angular acceleration must be investigated for airplanes with engines or other weight concentrations outboard of the fuselage. For the angular acceleration conditions, zero rolling velocity may be assumed in the absence of a rational time history investigation of the maneuver.

(2) At V_A, a sudden deflection of the aileron to the stop is assumed.

(3) At V_C, the aileron deflection must be that required to produce a rate of roll not less than that obtained in paragraph (a)(2) of this section.

(4) At V_D, the aileron deflection must be that required to produce a rate of roll not less than one-third of that in paragraph (a)(2) of this paragraph.

(b) *Unsymmetrical gusts.* [The airplane is assumed to be subjected to unsymmetrical vertical gusts in level flight. The resulting limit loads must be determined from either the wing maximum airload derived directly from § 25.341(a), or the wing maximum airload derived indirectly from the vertical load factor calculated from § 25.341(a). It must be assumed that 100 percent of the wing air load of this section. Unbalanced aerodynamic moments about the center of gravity must be reacted in a rational or conservative manner considering the principal masses furnishing the reacting inertia forces:]

(a) *Maneuvering.* At speeds from V_{MC} to V_D, the following maneuvers must be considered. In computing the tail loads, the yawing velocity may be assumed to be zero:

(1) With the airplane in unaccelerated flight at zero yaw, it is assumed that the rudder control is suddenly displaced to the maximum deflection, as limited by the control surface stops, or by a 300-pound rudder pedal force, whichever is less.

(2) With the rudder deflected as specified in paragraph (a)(1) of this section, it is assumed that the airplane yaws to the resulting sideslip angle.

(3) With the airplane yawed to the static sideslip angle corresponding to the rudder deflection specified in paragraph (a)(1) of this section, it is assumed that the rudder is returned to neutral.

(b) [Reserved]

(Amdt. 25–23, Eff. 5/8/70); (Amdt. 25–46, Eff. 12/1/78); (Amdt. 25–72, Eff. 8/20/90); [(Amdt. 25–86, Eff. 3/11/96)]

SUPPLEMENTARY CONDITIONS

§ 25.361 Engine torque.

(a) Each engine mount and its supporting structure must be designed for the effects of—

(1) A limit engine torque corresponding to takeoff power and propeller speed acting simultaneously with 75 percent of the limit loads from flight condition A of § 25.333(b);

(2) A limit torque corresponding to the maximum continuous power and propeller speed, acting simultaneously with the limit loads from flight condition A of § 25.333(b); and

(3) For turbopropeller installations, in addition to the conditions specified in paragraphs (a)(1) and (2) of this section, a limit engine torque

(1) A limit engine torque load imposed by sudden engine stoppage due to malfunction or structural failure (such as compressor jamming).

(2) A limit engine torque load imposed by the maximum acceleration of the engine.

(c) The limit engine torque to be considered under paragraph (a) of this section must be obtained by multiplying mean torque for the specified power and speed by a factor of—

(1) 1.25 for turbopropeller installations;

(2) 1.33 for reciprocating engines with five or more cylinders; or

(3) Two, three, or four, for engines with four, three, or two cylinders, respectively.

(Amdt. 25–23, Eff. 5/8/70); (Amdt. 25–46, Eff. 12/1/78); (Amdt. 25–72, Eff. 8/20/90)

§ 25.363 Side load on engine mount.

(a) Each engine mount and its supporting structure must be designed for a limit load factor in a lateral direction, for the side load on the engine mount, at least equal to the maximum load factor obtained in the yawing conditions but not less than—

(1) 1.33; or

(2) One-third of the limit load factor for flight condition A as prescribed in § 25.333 (b).

(b) The side load prescribed in paragraph (a) of this section may be assumed to be independent of other flight conditions.

(Amdt. 25–23, Eff. 5/8/70)

§ 25.365 Pressurized compartment loads.

For airplanes with one or more pressurized compartments the following apply:

(a) The airplane structure must be strong enough to withstand the flight loads combined with pressure differential loads from zero up to the maximum relief valve setting.

(b) The external pressure distribution in flight, and stress concentrations and fatigue effects must be accounted for.

outside a pressurized compartment, the failure of which could interfere with continued safe flight and landing, must be designed to withstand the effects of a sudden release of pressure through an opening in any compartment at any operating altitude resulting from each of the following conditions:

(1) The penetration of the compartment by a portion of an engine following an engine disintegration;

(2) Any opening in any pressurized compartment up to the size H_O in square feet; however, small compartments may be combined with an adjacent pressurized compartment and both considered as a single compartment for openings that cannot reasonably be expected to be confined to the small compartment. The size H_O must be computed by the following formula:

$$H_O = PA_S$$

where—

H_O = Maximum opening in square feet, need not exceed 20 square feet.

$$P = \frac{A_S}{6240} + .024$$

A_S = Maximum cross-sectional area of the pressurized shell normal to the longitudinal axis, in square feet; and

(3) The maximum opening caused by airplane or equipment failures not shown to be extremely improbable.

(f) In complying with paragraph (e) of this section, the fail-safe features of the design may be considered in determining the probability of failure or penetration and probable size of openings, provided that possible improper operation of closure devices and inadvertent door openings are also considered. Furthermore, the resulting differential pressure loads must be combined in a rational and conservative manner with 1-g level flight loads and any loads arising from emergency depressurization conditions. These loads may be considered as ultimate conditions; however, any deformations associated with these conditions must not interfere with continued safe flight and landing. The pressure

(Amdt. 25–54, Eff. 10/14/80); (Amdt. 25–71, Eff. 5/10/90); (Amdt. 25–72, Eff. 8/20/90)

§ 25.367 Unsymmetrical loads due to engine failure.

(a) The airplane must be designed for the unsymmetrical loads resulting from the failure of the critical engine. Turbopropeller airplanes must be designed for the following conditions in combination with a single malfunction of the propeller drag limiting system, considering the probable pilot corrective action on the flight controls:

(1) At speeds between V_{MC} and V_D, the loads resulting from power failure because of fuel flow interruption are considered to be limit loads.

(2) At speeds between V_{MC} and V_C, the loads resulting from the disconnection of the engine compressor from the turbine or from loss of the turbine blades are considered to be ultimate loads.

(3) The time history of the thrust decay and drag build-up occurring as a result of the prescribed engine failures must be substantiated by test or other data applicable to the particular engine-propeller combination.

(4) The timing and magnitude of the probable pilot corrective action must be conservatively estimated, considering the characteristics of the particular engine-propeller-airplane combination.

(b) Pilot corrective action may be assumed to be initiated at the time maximum yawing velocity is reached, but not earlier than two seconds after the engine failure. The magnitude of the corrective action may be based on the control forces specified in § 25.397(b) except that lower forces may be assumed where it is shown by analysis or test that these forces can control the yaw and roll resulting from the prescribed engine failure conditions.

§ 25.371 Gyroscopic loads.

[The structure supporting the engines and the auxiliary power units must be designed for the gyroscopic loads associated with the conditions specified in §§ 25.331, 25.341(a), 25.349 and 25.351

(a) [The airplane must be designed for the symmetrical maneuvers prescribed in § 25.333 and § 25.337, the yawing maneuvers prescribed in § 25.351, and the vertical and lateral gust conditions prescribed in § 25.341(a), at each setting and the maximum speed associated with that setting; and]

(b) If the device has automatic operating or load limiting features, the airplane must be designed for the maneuver and gust conditions designed for the maneuver and gust conditions prescribed in paragraph (a) of this section, at the speeds and corresponding device positions that the mechanism allows.

(Amdt. 25–72, Eff. 8/20/90); [(Amdt. 25–86, Eff. 3/11/96)]

CONTROL SURFACE AND SYSTEM LOADS

§ 25.391 Control surface loads: General.

[The control surfaces must be designed for the limit loads resulting from the flight conditions in §§ 25.331, 25.341(a), 25.349 and 25.351 and the ground gust conditions in § 25.415, considering the requirements for—]

(a) Loads parallel to hinge line, in § 25.393;

(b) Pilot effort effects, in § 25.397;

(c) Trim tab effects, in § 25.407;

(d) Unsymmetrical loads, in § 25.427; and

(e) [Auxiliary aerodynamic surfaces, in § 25.445.]

[(Amdt. 25–86, Eff. 3/11/96)]

§ 25.393 Loads parallel to hinge line.

(a) Control surfaces and supporting hinge brackets must be designed for inertia loads acting parallel to the hinge line.

(b) In the absence of more rational data, the inertia loads may be assumed to be equal to KW, where—

(1) K = 24 for vertical surfaces;

(2) K = 12 for horizontal surfaces; and

(3) W = weight of the movable surfaces.

resulting from ground gusts, need not exceed the loads that can be produced by the pilot (or pilots) and by automatic or power devices operating the controls.

(c) The loads must not be less than those resulting from application of the minimum forces prescribed in § 25.397(c).

(Amdt. 25–23, Eff. 5/8/70); (Amdt. 25–72, Eff. 8/20/90)

§ 25.397 Control system loads.

(a) *General.* The maximum and minimum pilot forces, specified in paragraph (c) of this section, are assumed to act at the appropriate control grips or pads (in a manner simulating flight conditions) and to be reacted at the attachment of the control system to the control surface horn.

(b) *Pilot effort effects.* In the control surface flight loading condition, the air loads on movable surfaces and the corresponding deflections need not exceed those that would result in flight from the application of any pilot force within the ranges specified in paragraph (c) of this section. Two-thirds of the maximum values specified for the aileron and elevator may be used if control surface hinge moments are based on reliable data. In applying this criterion, the effects of servo mechanisms, tabs, and automatic pilot systems, must be considered.

(c) *Limit pilot forces and torques.* The limit pilot forces and torques are as follows:

Control	Maximum forces or torques	Minimum forces or torques
Aileron:		
Stick	100 lbs.	40 lbs.
Wheel [1]	80 D in.-lbs.[2]	40 D in.-lbs.
Elevator:		
Stick	250 lbs.	100 lbs.
Wheel (symmetrical)	300 lbs.	100 lbs.
Wheel (unsymmetrical) [3]		100 lbs.
Rudder	300 lbs.	130 lbs.

[1] The critical parts of the aileron control system must be designed for a single tangential force with a limit value equal to 1.25 times the couple force determined from these criteria.

[2] D = wheel diameter (inches).

ual pilot forces not less than—

(1) 0.75 times those obtained under § 25.395; or

(2) The minimum forces specified in § 25.397(c).

(b) The control system must be designed for pilot forces applied in the same direction, using individual pilot forces not less than 0.75 times those obtained under § 25.395.

§ 25.405 Secondary control system.

Secondary controls, such as wheel brake, spoiler, and tab controls, must be designed for the maximum forces that a pilot is likely to apply to those controls. The following values may be used:

Pilot Control Force Limits (Secondary Controls)

Control	Limit pilot forces
Miscellaneous: *Crank, wheel, or lever	(1+R/3)×50 lbs., but not less than 50 lbs. nor more than 1501bs. (R = radius). (Applicable to any angle within 20° of plane of control).
Twist	133 in.-lbs.
Push-pull	To be chosen by applicant.

*Limited to flap, tab, stabilizer, spoiler, and landing gear operation controls.

§ 25.407 Trim tab affects.

The effects of trim tabs on the control surface design conditions must be accounted for only where the surface loads are limited by maximum pilot effort. In these cases, the tabs are considered to be deflected in the direction that would assist the pilot, and the deflections are—

(a) For elevator trim tabs, those required to trim the airplane at any point within the positive portion of the pertinent flight envelope in § 25.333(b), except as limited by the stops; and

(b) For aileron and rudder trim tabs, those required to trim the airplane in the critical unsymmetrical power and loading conditions, with appropriate allowance for rigging tolerances.

(b) *Balancing tabs.* Balancing tabs must be designed for deflections consistent with the primary control surface loading conditions.

(c) *Servo tabs.* Servo tabs must be designed for deflections consistent with the primary control surface loading conditions obtainable within the pilot maneuvering effort, considering possible opposition from the trim tabs.

§ 25.415 Ground gust conditions.

(a) The control system must be designed as follows for control surface loads due to ground gusts and taxiing downwind:

(1) The control system between the stops nearest the surfaces and the cockpit controls must be designed for loads corresponding to the limit hinge moments H of paragraph (a)(2) of this section. These loads need not exceed—

(i) The loads corresponding to the maximum pilot loads in § 25.397(c) for each pilot alone; or

(ii) 0.75 times these maximum loads for each pilot when the pilot forces are applied in the same direction.

(2) The control system stops nearest the surfaces, the control system locks, and the parts of the systems (if any) between these stops and locks and the control surface horns, must be designed for limit hinge moments H obtained from the formula, $H = KcS_s q$,

where—

H = limit hinge moment (ft. lbs.);

c = mean chord of the control surface aft of the hinge line (ft.);

S_s = area of the control surface aft of the hinge line (sq. ft.);

q = dynamic pressure (p.s.f.) based on a design speed not less than 14. √WSI+14.6 (f.p.s.), except that the design speed need not exceed 88 f.p.s. (W/S is wing loading based on maximum airplane weight and wing area); and

K = limit hinge moment factor for ground gusts derived in paragraph (b) of this section.

(b) The limit hinge moment factor K for ground gusts must be derived as follows:

tending to raise the surface.

(Amdt. 25–72, Eff. 8/20/90)

§ 25.427 Unsymmetrical loads.

[(a) In designing the airplane for lateral gust, yaw maneuver and roll maneuver conditions, account must be taken of unsymmetrical loads on the empennage arising from effects such as slipstream and aerodynamic interference with the wing, vertical fin and other aerodynamic surfaces.

[(b) The horizontal tail must be assumed to be subjected to unsymmetrical loading conditions determined as follows:

(1) 100 percent of the maximum loading from the symmetrical maneuver conditions of § 25.331 and the vertical gust conditions of § 25.341(a) acting separately on the surface on one side of the plane of symmetry; and

(2) 80 percent of these loadings acting on the other side.

[(c) For empennage arrangements where the horizontal tail surfaces have dihedral angles greater than plus or minus 10 degrees, or are supported by the vertical tail surfaces, the surfaces and the supporting structure must be designed for gust velocities specified in § 25.341(a) acting in any orientation at right angles to the flight path.

[(d) Unsymmetrical loading on the empennage arising from buffet conditions of § 25.305(e) must be taken into account.]

(Amdt. 25–23, Eff. 5/8/70); [(Amdt. 25–86, Eff. 3/11/96)]

§ 25.445 Outboard fins.

§ 25.445 [Auxiliary aerodynamic surfaces.]

(a) [When significant, the aerodynamic influence between auxiliary aerodynamic surfaces, such as outboard fins and winglets, and their supporting aerodynamic surfaces, must be taken into account for all loading conditions including pitch, roll, and yaw maneuvers, and gusts as specified in § 25.341(a) acting at any orientation at right angles to the flight path.]

[(Amdt. 25–86, Eff. 3/11/96)]

§ 25.457 Wing flaps.

Wing flaps, their operating mechanisms, and their supporting structures must be designed for critical loads occurring in the conditions prescribed in § 25.345, accounting for the loads occurring during transition from one flap position and airspeed to another.

§ 25.459 Special devices.

The loading for special devices using aerodynamic surfaces (such as slots, slats, and spoilers) must be determined from test data.

(Amdt. 25–72, Eff. 8/20/90)

GROUND LOADS

§ 25.471 General.

(a) *Loads and equilibrium.* For limit ground loads—

(1) Limit ground loads obtained under this subpart are considered to be external forces applied to the airplane structure; and

(2) In each specified ground load condition, the external loads must be placed in equilibrium with the linear and angular inertia loads in a rational or conservative manner.

(b) *Critical centers of gravity.* The critical centers of gravity within the range for which certification is requested must be selected so that the maximum design loads are obtained in each landing gear element. Fore and aft, vertical, and lateral airplane centers of gravity must be considered. Lateral displacements of the c.g. from the airplane centerline which would result in main gear loads not greater than 103 percent of the critical design load for symmetrical loading conditions may be selected without considering the effects of these lateral c.g. displacements on the loading of the main gear elements, or on the airplane structure provided—

(1) The lateral displacement of the c.g. results from random passenger or cargo disposition

dimension data.

(Amdt. 25–23, Eff. 5/8/70)

§ 25.473 Ground load conditions and assumptions.

(a) For the landing conditions specified in §§ 25.479 through 25.485, the following apply:

(1) The selected limit vertical inertia load factors at the center of gravity of the airplane may not be less than the values that would be obtained—

(i) In the attitude and subject to the drag loads associated with the particular landing condition;

(ii) With a limit descent velocity of 10 f.p.s. at the design landing weight (the maximum weight for landing conditions at the maximum descent velocity); and

(iii) With a limit descent velocity of 6 f.p.s. at the design takeoff weight (the maximum weight for landing conditions at a reduced descent velocity).

(2) Airplane lift, not exceeding the airplane weight, may be assumed to exist throughout the landing impact and to act through the center of gravity of the airplane.

(b) The prescribed descent velocities may be modified if it is shown that the airplane has design features that make it impossible to develop these velocities.

(c) The minimum limit inertia load factors corresponding to the required limit descent velocities must be determined in accordance with § 25.723(a).

(Amdt. 25–23, Eff. 5/8/70)

§ 25.477 Landing gear arrangement.

Sections 25.479 through 25.485 apply to airplanes with conventional arrangements of main and nose gears, or main and tail gears, when normal operating techniques are used.

tions, and

(2) V_{L2} equal to V_{SO} (TAS) at the appropriate landing weight and altitudes in a hot-day temperature of 41° F. above standard.

(b) The effects of increased contact speeds must be investigated if approval of downwind landings exceeding 10 knots is desired.

(c) Assuming that the following combinations of vertical and drag components act at the axle centerline, the following apply:

(1) For the condition of maximum wheel spin-up load, drag components simulating the forces required to accelerate the wheel rolling assembly up to the specified ground speed must be combined with the vertical ground reactions existing at the instant of peak drag loads. The coefficient of friction between the tires and the ground may be established by considering the effects of skidding velocity and tire pressure. However, this coefficient of friction need not be more than 0.8. This condition must be applied to the landing gear, directly affected attaching structure, and large mass items such as external fuel tanks and nacelles.

(2) For the condition of maximum wheel vertical load, an aft acting drag component of not less than 25 percent of the maximum vertical ground reaction must be combined with the maximum ground reaction of § 25.473.

(3) For the condition of maximum springback load, forward-acting horizontal loads resulting from a rapid reduction of the spin-up drag loads must be combined with the vertical ground reactions at the instant of the peak forward load. This condition must be applied to the landing gear, directly affected attaching structure, and large mass items such as external fuel tanks and nacelles.

(d) For the level landing attitude for airplanes with tail wheels, the conditions specified in paragraphs (a) through (c) of this section must be investigated with the airplane horizontal reference line horizontal in accordance with figure 2 of appendix A.

(e) For the level landing attitude for airplanes with nose wheels, shown in figure 2 of appendix which the nose and main wheels are assumed to contact the ground simultaneously. For this attitude—

(i) The nose and main gear may be separately investigated under the conditions in paragraph (c)(1) and (3) of this section; and

(ii) The pitching moment is assumed, under the condition in paragraph (c)(2) of this section, to be resisted by the nose gear.

(Amdt. 25–23, Eff. 5/8/70)

§ 25.481 Tail-down landing conditions.

(a) In the tail-down attitude, the airplane is assumed to contact the ground at forward velocity components, ranging from V_{L1} to V_{L2}, parallel to the ground, and is subjected to the load factors prescribed in § 25.473(a)(1) with—

(1) V_{L1} equal to V_{SO} (TAS) at the appropriate landing weight and in standard sea level conditions; and

(2) V_{L2} equal to V_{SO} (TAS) at the appropriate landing weight and altitudes in a hot-day temperature of 41° F. above standard.

The combination of vertical and drag components specified in § 25.479(c)(1) and (3) is considered to be acting at the main wheel axle centerline.

(b) For the tail-down landing condition for airplanes with tail wheels, the main and tail wheels are assumed to contact the ground simultaneously, in accordance with figure 3 of appendix A. Ground reaction conditions on the tail wheel are assumed to act—

(1) Vertically; and

(2) Up and aft through the axle at 45 degrees to the ground line.

(c) For the tail-down landing condition for airplanes with nose wheels, the airplane is assumed to be at an attitude corresponding to either the stalling angle of the maximum angle allowing clearance with the ground by each part of the airplane other than the main wheels, in accordance with figure 3 of appendix A, whichever is less.

and

(b) Each unbalanced external load must be reacted by airplane inertia in a rational or conservative manner.

§ 25.485 Side load conditions.

(a) For the side load condition, the airplane is assumed to be in the level attitude with only the main wheels contacting the ground, in accordance with figure 5 of appendix A.

(b) Side loads of 0.8 of the vertical reaction (on one side) acting inward and 0.6 of the vertical reaction (on the other side) acting outward must be combined with one-half of the maximum vertical ground reactions obtained in the level landing conditions. These loads are assumed to be applied at the ground contact point and to be resisted by the inertia of the airplane. The drag loads may be assumed to be zero.

§ 25.487 Rebound landing condition.

(a) The landing gear and its supporting structure must be investigated for the loads occurring during rebound of the airplane from the landing surface.

(b) With the landing gear fully extended and not in contact with the ground, a load factor of 20.0 must act on the unsprung weights of the landing gear. This load factor must act in the direction of motion of the unsprung weights as they reach their limiting positions in extending with relation to the sprung parts of the landing gear.

§ 25.489 Ground handling conditions.

Unless otherwise prescribed, the landing gear and the airplane structure must be investigated for the conditions in §§ 25.491 through 25.509 with the airplane at the design ramp weight (the maximum weight for ground handling conditions). No wing lift may be considered. The shock absorbers and tires may be assumed to be in their static position.

(Amdt. 25–23, Eff. 5/8/70)

to be in the level attitude with the load on the main wheels, in accordance with figure 6 of appendix A. The limit vertical load factor is 1.2 at the design landing weight, and 1.0 at the design ramp weight. A drag reaction equal to the vertical reaction multiplied by a coefficient of friction of 0.8, must be combined with the vertical ground reaction and applied at the ground contact point.

(b) For an airplane with a nose wheel, the limit vertical load factor is 1.2 at the design landing weight, and 1.0 at the design ramp weight. A drag reaction equal to the vertical reaction, multiplied by a coefficient of friction of 0.8, must be combined with the vertical reaction and applied at the ground contact point of each wheel with brakes. The following two attitudes, in accordance with figure 6 of appendix A, must be considered:

(1) The level attitude with the wheels contacting the ground and the loads distributed between the main and nose gear. Zero pitching acceleration is assumed.

(2) The level attitude with only the main gear contacting the ground and with the pitching moment resisted by angular acceleration.

(c) A drag reaction lower than that prescribed in paragraphs (a) and (b) of this section may be used if it is substantiated that an effective drag force of 0.8 times the vertical reaction cannot be attained under any likely loading condition.

(Amdt. 25–23, Eff. 5/8/70)

§ 25.495 Turning.

In the static position, in accordance with figure 7 of appendix A, the airplane is assumed to execute a steady turn by nose gear steering, or by application of sufficient differential power, so that the limit load factors applied at the center of gravity are 1.0 vertically and 0.5 laterally. The side ground reaction of each wheel must be 0.5 of the vertical reaction.

§ 25.497 Tail-wheel yawing.

(a) A vertical ground reaction equal to the static load on the tail wheel, in combination with a side component of equal magnitude, is assumed.

§ 25.499 Nose-wheel yaw.

(a) A vertical load factor of 1.0 at the airplane center of gravity, and a side component at the nose wheel ground contact equal to 0.8 of the vertical ground reaction at that point are assumed.

(b) With the airplane assumed to be in static equilibrium with the loads resulting from the use of brakes on one side of the main landing gear, the nose gear, its attaching structure, and the fuselage structure forward of the center of gravity must be designed for the following loads:

(1) A vertical load factor at the center of gravity of 1.0.

(2) A forward acting load at the airplane center of gravity of 0.8 times the vertical load on one main gear.

(3) Side and vertical loads at the ground contact point on the nose gear that are required for static equilibrium.

(4) A side load factor at the airplane center of gravity of zero.

(c) If the loads prescribed in paragraph (b) of this section result in a nose gear side load higher than 0.8 times the vertical nose gear load, the design nose gear side load may be limited to 0.8 times the vertical load, with unbalanced yawing moments assumed to be resisted by airplane inertia forces.

(d) For other than the nose gear, its attaching structure, and the forward fuselage structure the loading conditions are those prescribed in paragraph (b) of this section, except that—

(1) A lower drag reaction may be used if an effective drag force of 0.8 times the vertical reaction cannot be reached under any likely loading condition; and

(2) The forward acting load at the center of gravity need not exceed the maximum drag reaction on one main gear, determined in accordance with § 25.493(b).

(e) With the airplane at design ramp weight, and the nose gear in any steerable position, the combined application of full normal steering torque and a vertical force equal to the maximum static reaction on the nose gear must be considered in design-locked. The limit vertical load factor must be 1.0 and the coefficent of friction 0.8.

(b) The airplane is assumed to be in static equilibrium, with the loads being applied at the ground contact points, in accordance with figure 8 of appendix A.

§ 25.507 Reversed braking.

(a) The airplane must be in a three point static ground attitude. Horizontal reactions parallel to the ground and directed forward must be applied at the ground contact point of each wheel with brakes. The limit loads must be equal to 0.55 times the vertical load at each wheel or to the load developed by 1.2 times the nominal maximum static brake torque, whichever is less.

(b) For airplanes with nose wheels, the pitching moment must be balanced by rotational inertia.

(c) For airplanes with tail wheels, the resultant of the ground reactions must pass through the center of gravity of the airplane.

§ 25.509 Towing loads.

(a) The towing loads specified in paragraph (d) of this section must be considered separately. These loads must be applied at the towing fittings and must act parallel to the ground. In addition—

50,000 and 100,000 pounds; and

(iii) 0.15 W_T for W_T over 100,000 pounds.

(b) For towing points not on the landing gear but near the plane of symmetry of the airplane, the drag and side tow load components specified for the auxiliary gear apply. For towing points located outboard of the main gear, the drag and side tow load components specified for the main gear apply. Where the specified angle of swivel cannot be reached, the maximum obtainable angle must be used.

(c) The towing loads specified in paragraph (d) of this section must be reacted as follows:

(1) The side component of the towing load at the main gear must be reacted by a side force at the static ground line of the wheel to which the load is applied.

(2) The towing loads at the auxiliary gear and the drag components of the towing loads at the main gear must be reacted as follows:

(i) A reaction with a maximum value equal to the vertical reaction must be applied at the axle of the wheel to which the load is applied. Enough airplane inertia to achieve equilibrium must be applied.

(ii) The loads must be reacted by airplane inertia.

(d) The prescribed towing loads are as follows:

Tow point	Position	Load		
		Magnitude	No.	Direction
Main gear		0.75 F_{TOW} per main gear unit	1	Forward, parallel to drag axis.
			2	Forward, at 30° to drag axis.
			3	Aft, parallel to drag axis.
			4	Aft, at 30° to drag axis.
Auxiliary gear	Swiveled forward	1.0 F_{TOW}	5	Forward.
	Swiveled aft	do	6	Aft.
	Swiveled 45° from forward	0.5 F_{TOW}	7	Forward.
	Swiveled 45° from aft	do	8	Aft.
			9	Forward, in plane of wheel.
			10	Aft, in plane of wheel.
			11	Forward, in plane of wheel.
			12	Aft, in plane of wheel.

(1) A tandem strut gear arrangement is a multiple-wheel unit; and

(2) In determining the total load on a gear unit with respect to the provisions of paragraphs (b) through (f) of this section, the transverse shift in the load centroid, due to unsymmetrical load distribution on the wheels, may be neglected.

(b) *Distribution of limit loads to wheels; tires inflated.* The distribution of the limit loads among the wheels of the landing gear must be established for each landing, taxiing, and ground handling condition, taking into account the effects of the following factors:

(1) The number of wheels and their physical arrangements. For truck type landing gear units, the effects of any see-saw motion of the truck during the landing impact must be considered in determining the maximum design loads for the fore and aft wheel pairs.

(2) Any differentials in tire diameters resulting from a combination of manufacturing tolerances, tire growth, and tire wear. A maximum tire-diameter differential equal to ⅔ of the most unfavorable combination of diameter variations that is obtained when taking into account manufacturing tolerances, tire growth, and tire wear, may be assumed.

(3) Any unequal tire inflation pressure, assuming the maximum variation to be ±5 percent of the nominal tire inflation pressure.

(4) A runway crown of zero and a runway crown having a convex upward shape that may be approximated by a slope of 1½ percent with the horizontal. Runway crown effects must be considered with the nose gear unit on either slope of the crown.

(5) The airplane attitude.

(6) Any structural deflections.

(c) *Deflated tires.* The effect of deflated tires on the structure must be considered with respect to the loading conditions specified in paragraphs (d) through (f) of this section, taking into account the physical arrangement of the gear components. In addition—

(1) The deflation of any one tire for each multiple wheel landing gear unit, and the deflation of any two critical tires for each landing gear unit using four or more wheels per unit, must be considered; and

(2) The ground reactions must be applied to the wheels with inflated tires except that, for multiple-wheel gear units with more than one shock strut, a rational distribution of the ground reactions between the deflated and inflated tires, accounting for the differences in shock strut extensions resulting from a deflated tire, may be used.

(d) *Landing conditions.* For one and for two deflated tires, the applied load to each gear unit is assumed to be 60 percent and 50 percent, respectively, of the limit load applied to each gear for each of the prescribed landing conditions. However, for the drift landing condition of § 25.485, 100 percent of the vertical load must be applied.

(e) *Taxiing and ground handling conditions.* For one and for two deflated tires—

(1) The applied side or drag load factor, or both factors, at the center of gravity must be the most critical value up to 50 percent and 40 percent, respectively, of the limit side or drag load factors, or both factors, corresponding to the most severe condition resulting from consideration of the prescribed taxiing and ground handling conditions;

(2) For the braked roll conditions of § 25.493 (a) and (b)(2), the drag loads on each inflated tire may not be less than those at each tire for the symmetrical load distribution with no deflated tires.

(3) The vertical load factor at the center of gravity must be 60 percent and 50 percent, respectively, of the factor with no deflated tires, except that it may not be less than 1g; and

(4) Pivoting need not be considered.

(f) *Towing conditions.* For one and for two deflated tires, the towing load, F_{tow}, must be 60 percent and 50 percent, respectively, of the load prescribed.

[§ 25.519 Jacking and tie-down provisions.

[(a) *General.* The airplane must be designed to withstand the limit load conditions resulting from the static ground load conditions of paragraph (b) and, if applicable, paragraph (c) of this section at the most critical combinations of airplane weight and center of gravity. The maximum allowable limit load at each jack pad must be specified.

(b) *Jacking.* The airplane must have provisions for jacking and must withstand the following limit loads when the airplane is supported on jacks—

(i) The airplane structure must be designed for a vertical load of 1.33 times the vertical static reaction at each jacking point acting singly and in combination with a horizontal load of 0.33 times the vertical static reaction applied in any direction.

(ii) The jacking pads and local structure must be designed for a vertical load of 2.0 times the vertical static reaction at each jacking point, acting singly and in combination with a horizontal load of 0.33 times the vertical static reaction applied in any direction.

(c) *Tie-down.* If tie-down points are provided, the main tie-down points and local structure must withstand the limit loads resulting from a 65-knot horizontal wind from any direction.]

[(Amdt. 25–81, Eff. 5/31/94)]

WATER LOADS

§ 25.521 General

(a) Seaplanes must be designed for the water loads developed during takeoff and landing, with the seaplane in any attitude likely to occur in normal operation, and at the appropriate forward and sinking velocities under the most severe sea conditions likely to be encountered.

(b) Unless a more rational analysis of the water loads is made, or the standards in ANC–3 are used in §§ 25.523 through 25.537 apply.

(c) The requirements of this section and §§ 25.523 through 25.537 apply also to amphibians.

§ 25.523 Designs weights and center of gravity positions.

(a) *Design weights.* The water load requirements must be met at each operating weight up to the design landing weight except, that, for the takeoff condition prescribed in § 25.531, the design water takeoff weight (the maximum weight for water taxi and takeoff run) must be used.

(b) *Center of gravity positions.* The critical centers of gravity within the limits for which certification is requested must be considered to reach § 25.527.

(b) In applying the loads resulting from the load factors prescribed in § 25.527, the loads may be distributed over the hull or main float bottom (in order to avoid excessive local shear loads and bending moments at the location of water load application) using pressures not less than those prescribed in § 25.533(b).

(c) For twin float seaplanes, each float must be treated as an equivalent hull on a fictitious seaplane with a weight equal to ½ the weight of the twin float seaplane.

(d) Except in the takeoff condition of § 25.531, the aerodynamic lift on the seaplane during the impact is assumed to be ⅔ of the weight of the seaplane.

§ 25.527 Hull and main float load factors.

(a) Water reaction load factors must be computed in the following manner:

(1) For the step landing case

$$N_w = \frac{C_1 V_{SO}^2}{(\mathrm{Tan}^{2/3}\,\beta)\, W^{1/3}}$$

(2) For the bow and stem landing cases

$$N_w = \frac{C_1 V_{SO}^2}{(\mathrm{Tan}^{2/3}\,\beta)\, W^{1/3}} \times \frac{K_1}{(1+r_x{}^2)^{2/3}}$$

where—

n_w = water reaction load factor (that is, the water reaction divided by seaplane weight).

C_1 = empirical seaplane operations factor equal to 0.012 (except that this factor may not be less than that necessary to obtain the minimum value of step load factor of 2.33) .

V_{SO} = seaplane stalling speed in knots with flaps extended in the appropriate landing position and with no slipstream effect.

β = angle of dead rise at the longitudinal station at which the load factor is being determined in accordance with figure 1 of appendix B.

W = seaplane design landing weight in pounds.

effect of flexibility of the attachment of the floats to the seaplane, the factor K_1 may be reduced at the bow and stern to 0.8 of the value shown in figure 2 of appendix B. This reduction applies only to the design of the carrythrough and seaplane structure.

(Amdt. 25–23, Eff. 5/8/70)

§ 25.529 Hull and main float landing conditions.

(a) *Symmetrical step, bow, and stern landing.* For symmetrical step, bow, and stern landings, the limit water reaction load factors are those computed under § 25.527. In addition—

(1) For symmetrical step landings, the resultant water load must be applied at the keel, through the center of gravity, and must be directed perpendicularly to the keel line;

(2) For symmetrical bow landings, the resultant water load must be applied at the keel, ⅕ of the longitudinal distance from the bow to the step, and must be directed perpendicularly to the keel line; and

(3) For symmetrical stern landings, the resultant water load must be applied at the keel, at a point 85 percent of the longitudinal distance from the step to the stern post, and must be directed perpendicularly to the keel line.

(b) *Unsymmetrical landing for hull and single float seaplanes.* Unsymmetrical step, bow, and stern landing conditions must be investigated. In addition—

(1) The loading for each condition consists of an upward component and a side component equal, respectively, to 0.75 and 0.25 tan β times the resultant load in the corresponding symmetrical landing condition; and

(2) The point of application and direction of the upward component of the load is the same as that in the symmetrical condition, and the point of application of the side component is at the same longitudinal station as the upward component but is directed inward perpendicularly to the plane of symmetry at a point midway between the keel and chine lines.

§ 25.531 Hull and main float takeoff condition.

For the wing and its attachment to the hull or main float—

(a) The aerodynamic wing lift is assumed to be zero; and

(b) A downward inertia load, corresponding to a load factor computed from the following formula, must be applied:

$$N = \frac{C_{TO} V_{S1}^2}{(\tan^{2/3} \beta)\, W^{1/3}}$$

where—

n = inertia load factor;

C_{TO} = empirical seaplane operations factor equal to 0.004;

V_{S1} = seaplane stalling speed (knots) at the design takeoff weight with the flaps extended in the appropriate takeoff position;

β = angle of dead rise at the main step (degrees); and

W = design water takeoff weight in pounds.

(Amdt. 25–23, Eff. 5/8/70)

§ 25.533 Hull and main float bottom pressures.

(a) *General.* The hull and main float structure, including frames and bulkheads, stringers, and bottom plating, must be designed under this section.

(b) *Local pressures.* For the design of the bottom plating and stringers and their attachments to the supporting structure, the following pressure distributions must be applied:

(1) For an unflared bottom, the pressure at the chine is 0.75 times the pressure at the keel, and the pressures between the keel and chine vary linearly, in accordance with figure 3 of appendix B. The pressure at the keel (p.s.i.) is computed as follows:

$$P_k = C_2 \times \frac{K_2 V_{S1}^2}{\tan \beta_k}$$

where—

P_k = pressure (p.s.i.) at the chine;

an unflared bottom, and the pressure between the chine and the beginning of the flare varies linearly, in accordance with figure 3 of appendix B. The pressure distribution is the same as that prescribed in paragraph (b)(1) of this section for an unflared bottom except that the pressure at the chine is computed as follows:

$$P_{ch} = C_3 \times \frac{K_2 V_{S1}^2}{\tan \beta}$$

where—

P_{ch} = pressure (p.s.i.) at the chine;

C_3 = 0.0016;

K_2 = hull station weighing factor, in accordance with figure 2 of appendix B;

V_{S1} = seaplane stalling speed (knots) at the design water takeoff weight with flaps extended in the appropriate takeoff position; and

β = angle of dead rise at appropriate station.

The area over which these pressures are applied must simulate pressures occurring during high localized impacts on the hull or float, but need not extend over an area that would induce critical stresses in the frames or in the overall structure.

(c) *Distributed pressures.* For the design of the frames, keel, and chine structure, the following pressure distributions apply:

(1) Symmetrical pressures are computed as follows:

$$P = C_4 \times \frac{K_2 V_{S0}^2}{\tan \beta}$$

where—

P = pressure (p.s.i.);

$C_4 = 0.078\ C_1$, (with C_1, computed under § 25.527);

K_2 = hull station weighing factor, determined in accordance with figure 2 of appendix B;

V_{S0} = seaplane stalling speed (knots) with landing flaps extended in the appropriate position and with no slipstream effect; and

β = angle of dead rise at appropriate station.

(2) The unsymmetrical pressure distribution consists of the pressures prescribed in paragraph not be transmitted in a fore and aft direction as shear and bending loads.

(Amdt. 25–23, Eff. 5/8/70)

§ 25.535 Auxiliary float loads.

(a) *General.* Auxiliary floats and their attachments and supporting structures must be designed for the conditions prescribed in this section. In the cases specified in paragraphs (b) through (e) of this section, the prescribed water loads may be distributed over the float bottom to avoid excessive local loads, using bottom pressures not less than those prescribed in paragraph (g) of this section.

(b) *Step loading.* The resultant water load must be applied in the plane of symmetry of the float at a point three-fourths of the distance from the bow to the step and must be perpendicular to the keel. The resultant limit load is computed as follows, except that the value of L need not exceed three times the weight of the displaced water when the float is completely submerged:

$$L = \frac{C_5 V_{S0}^2\ W^{2/3}}{\tan^{2/3} \beta_S (1+r_y^2)^{2/3}}$$

where—

L = Limit load (lbs.);

C_5 = 0.0053;

V_{S0} = seaplane stalling speed (knots) with landing flaps extended in the appropriate position and with no slipstream effect;

W = seaplane design landing weight in pounds;

β_S = angle of dead rise at a station ¾ of the distance from the bow to the step, but need not be less than 15 degrees; and

r_y = ratio of the lateral distance between the center of gravity and the plane of symmetry of the float to the radius of gyration in roll.

(c) *Bow loading.* The resultant limit load must be applied in the plane of symmetry of the float at a point one-fourth of the distance from the bow to the step and must be perpendicular to the tangent to the keel line at that point. The magnitude of the resultant load is that specified in paragraph (b) of this section.

water load consists of a component equal to 0.75 times the load specified in paragraph (b) of this section and a side component equal to 0.25 tan β times the load specified in paragraph (c) of this section. The side load must be applied perpendicularly to the plane of symmetry at a point midway between the keel and the chine.

(f) *Immersed float condition.* The resultant load must be applied at the centroid of the cross section of the float at a point one-third of the distance from the bow to the step. The limit load components are as follows:

vertical = ρgV.

aft = $C_{x2}\rho V^{2/3}(KV_{SO})^2$.

side = $C_{y2}\rho V^{2/3}(KV_{SO})^2$.

where—

ρ = mass density of water (slugs/ft.^{2});

V = volume of float (ft.^{2});

C_X = coefficient of drag force, equal to 0.133;

C_y = coefficient of side force, equal to 0.106;

K = 0.8, except that lower values may be used if it is shown that the floats are incapable of submerging at a speed of 0.8 V_{SO} in normal operations;

V_{SO} = seaplane stalling speed (knots) with landing flaps extended in the appropriate position and with no slipstream effect; and

g = acceleration due to gravity (ft/sec^2).

(g) *Float bottom pressures.* The float bottom pressures must be established under § 25.533, except that the value of K_2 in the formulae may be taken as 1.0. The angle of dead rise to be used in determining the float bottom pressures is set forth in paragraph (b) of this section.

(Amdt. 25–23, Eff. 5/8/70)

§ 25.537 Seawing loads.

Seawing design loads must be based on applicable test data.

EMERGENCY LANDING CONDITIONS

§ 25.561 General.

(a) The airplane, although it may be damaged in emergency landing conditions on land or water,

(3) The occupant experiences the following ultimate inertia forces acting separately relative to the surrounding structure:

(i) Upward, 3.0g.

(ii) Forward, 9.0g.

(iii) Sideward, 3.0g on the airframe; and 4.0g on the seats and their attachments.

(iv) Downward, 6.0g.

(v) Rearward, 1.5g.

(c) The supporting structure must be designed to restrain, under all loads up to those specified in paragraph (b)(3) of this section, each item of mass that could injure an occupant if it came loose in a minor crash landing.

(d) Seats and items of mass (and their supporting structure) must not deform under any loads up to those specified in paragraph (b)(3) of this section in any manner that would impede subsequent rapid evacuation of occupants.

(Amdt. 25–23, Eff. 5/8/70); (Amdt. 25–64, Eff. 6/16/88)

§ 25.562 Emergency landing dynamic conditions.

(a) The seat and restraint system in the airplane must be designed as prescribed in this section to protect each occupant during an emergency landing condition when—

(1) Proper use is made of seats, safety belts, and shoulder harnesses provided for in the design; and

(2) The occupant is exposed to loads resulting from the conditions prescribed in this section.

(b) Each seat type design approved for crew or passenger occupancy during takeoff and landing must successfully complete dynamic tests or be demonstrated by rational analysis based on dynamic tests of a similar type seat, in accordance with each of the following emergency landing conditions. The tests must be conducted with an occupant simulated by a 170-pound anthropomorphic test dummy, as defined by 49 CFR part 572, subpart B, or its equivalent, sitting in the normal upright position.

the airplane's longitudinal axis horizontal and yawed 10 degrees either right or left, whichever would cause the greatest likelihood of the upper torso restraint system (where installed) moving off the occupant's shoulder, and with the wings level. Peak floor deceleration must occur in not more than 0.09 second after impact and must reach a minimum of 16g. Where floor rails or floor fittings are used to attach the seating devices to the test fixture, the rails or fittings must be misaligned with respect to the adjacent set of rails or fittings by at least 10 degrees vertically (i.e., out of parallel) with one rolled 10 degrees.

(c) The following performance measures must not be exceeded during the dynamic tests conducted in accordance with paragraph (b) of this section:

(1) Where upper torso straps are used for crewmembers, tension loads in individual straps must not exceed 1,750 pounds. If dual straps are used for restraining the upper torso, the total strap tension loads must not exceed 2,000 pounds.

(2) The maximum compressive load measured between the pelvis and the lumbar column of the anthropomorphic dummy must not exceed 1,500 pounds.

(3) The upper torso restraint straps (where installed) must remain on the occupant's shoulder during the impact.

(4) The lap safety belt must remain on the occupant's pelvis during the impact.

(5) Each occupant must be protected from serious head injury under the conditions prescribed in paragraph (b) of this section. Where head contact with seats or other structure can occur, protection must be provided so that the head impact does not exceed a Head Injury Criterion (HIC) of 1,000 units. The level of HIC is defined by the equation:

$$HIC = \left\{ (t_2 - t_1) \left[\frac{1}{(t_2 - t_1)} \int_{t_1}^{t_2} a(t)dt \right]^{2.5} \right\}_{max}$$

where—

t_1 is the initial integration time,

of attachment, although the structure may have yielded.

(8) Seats must not yield under the tests specified in paragraphs (b)(1) and (b)(2) of this section to the extent they would impede rapid evacuation of the airplane occupants.

(Amdt. 25–64, Eff. 6/16/88)

§ 25.563 Structural ditching provisions.

Structural strength considerations of ditching provisions must be in accordance with § 25.801(e).

FATIGUE EVALUATION

§ 25.571 Damage-tolerance and fatigue evaluation of structure.

(a) *General.* An evaluation of the strength, detail design, and fabrication must show that catastrophic failure due to fatigue, corrosion, or accidental damage, will be avoided throughout the operational life of the airplane. This evaluation must be conducted in accordance with the provisions of paragraphs (b) and (e) of this section, except as specified in paragraph (c) of this section, for each part of the structure which could contribute to a catastrophic failure (such as wing, empennage, control surfaces and their systems, the fuselage, engine mounting, landing gear, and their related primary attachments). Advisory Circular AC No. 25.571–1 contains guidance information relating to the requirements of this section (copies of the Advisory Circular may be obtained from the U.S. Department of Transportation, Publications Section M–443.1, Washington, DC 20590). For turbojet powered airplanes, those parts which could contribute to a catastrophic failure must also be evaluated under paragraph (d) of this section. In addition, the following apply:

(1) Each evaluation required by this section must include—

(i) The typical loading spectra, temperatures, and humidities expected in service;

(ii) The identification of principal structural elements and detail design points, the failure ferences in operating conditions and procedures, may be used in the evaluations required by this section.

(3) Based on the evaluations required by this section, inspections or other procedures must be established as necessary to prevent catastrophic failure, and must be included in the Airworthiness Limitations section of the Instructions for Continued Airworthiness required by § 25.1529.

(b) *Damage-tolerance evaluation.* The evaluation must include a determination of the probable locations and modes of damage due to fatigue, corrosion, or accidental damage. The determination must be the analysis supported by test evidence and (if available) service experience. Damage at multiple sites due to prior fatigue exposure must be included where the design is such that this type of damage can be expected to occur. The evaluation must incorporate repeated load and static analyses supported by test evidence. The extent of damage for residual strength evaluation at any time within the operational life must be consistent with the initial detectability and subsequent growth under repeated loads. The residual strength evaluation must show that the remaining structure is able to withstand loads (considered as static ultimate loads) corresponding to the following conditions:

(1) The limit symmetrical maneuvering conditions specified § 25.337 at V_C and in § 25.345.

(2) [The limit gust conditions specified in § 25.341 at the specified speeds up to V_C and in § 25.345.

(3) [The limit rolling conditions specified in § 25.349 and the limit unsymmetrical conditions specified in §§ 25.367 and 25.427 (a) through (c), at speeds up to V_C.]

(4) The limit yaw maneuvering conditions specified in § 25.351(a) at the specified speeds up to V_C.

(5) For pressurized cabins, the following conditions:

(i) The normal operating differential pressure combined with the expected external aerodynamic pressures applied simultaneously with the flight loading conditions specified in paragraphs (b)(1) through (4) of this section, if they have a significant effect.

tions specified in §§ 25.473, 25.491, and 25.493. If significant changes in structural stiffness or geometry, or both, follow from a structural failure, or partial failure, the effect on damage tolerance must be further investigated.

(c) *Fatigue (safe-life) evaluation.* Compliance with the damage-tolerance requirements of paragraph (b) of this section is not required if the applicant establishes that their application for particular structure is impractical. This structure must be shown by analysis, supported by test evidence, to be able to withstand the repeated loads of variable magnitude expected during its service life without detectable cracks. Appropriate safe-life scatter factors must be applied.

(d) *Sonic fatigue strength.* It must be shown by analysis, supported by test evidence, or by the service history of airplanes of similar structural design and sonic excitation environment, that—

(1) Sonic fatigue cracks are not probable in any part of the flight structure subject to sonic excitation; or

(2) Catastrophic failure caused by sonic cracks is not probable assuming that the loads prescribed in paragraph (b) of this section are applied to all areas affected by those cracks.

(e) *Damage-tolerance (discrete source) evaluation.* The airplane must be capable of successfully completing a flight during which likely structural damage occurs as a result of—

(1) Impact with a 4-pound bird at V_c at sea level to 8,000 feet;

(2) Uncontained fan blade impact;

(3) Uncontained engine failure; or

(4) Uncontained high energy rotating machinery failure.

The damaged structure must be able to withstand the static loads (considered as ultimate loads) which are reasonably expected to occur on the flight. Dynamic effects on these static loads need not be considered. Corrective action to be taken by the pilot following the incident, such as limiting maneuvers, avoiding turbulence, and reducing speed, must be considered. If significant changes in structural stiffness or geometry, or both, follow from a struc-

LIGHTNING PROTECTION

§ 25.581 Lightning protection.

(a) The airplane must be protected against catastrophic effects from lightning.

(1) Designing the components to minimize the effect of a strike; or

(2) Incorporating acceptable means of diverting the resulting electrical current so as not to endanger the airplane.

(Amdt. 25–23, Eff. 5/8/70)

§ 25.1501 General.

(a) Each operating limitation specified in §§ 25.1503 through 25.1533 and other limitations and information necessary for safe operation must be established.

(b) The operating limitations and other information necessary for safe operation must be made available to the crewmembers as prescribed in §§ 25.1541 through 25.1587.

(Amdt. 25–42, Eff. 3/1/78)

OPERATING LIMITATIONS

§ 25.1503 Airspeed limitations: General.

When airspeed limitations are a function of weight, weight distribution, altitude, or Mach number, limitations corresponding to each critical combination of these factors must be established.

§ 25.1505 Maximum operating limit speed.

The maximum operating limit speed (V_{MO}/M_{MO} airspeed or Mach number, whichever is critical at a particular altitude) is a speed that may not be deliberately exceeded in any regime of flight (climb, cruise, or descent), unless a higher speed is authorized for flight test or pilot training operations. V_M/M_{MO} must be established so that it is not greater than the design cruising speed V_c and so that it is sufficiently below V_D/M_D or V_{DF}/M_{DF} to make it highly improbable that the latter speeds will be inadvertently exceeded in operations. The speed margin between V_{MO}/M_{MO} and V_D/M_D or V_{DF}/M_{DF} may not be less than that determined under § 25.335(b) or found necessary during the flight tests conducted under § 25.253.

(Amdt. 25–23, Eff. 5/8/70)

§ 25.1507 Maneuvering speed.

The maneuvering speed must be established so that it does not exceed the design maneuvering speed V_A determined under § 25.335(c).

§ 25.1511 Flap extended speed.

The established flap extended speed V_{FE} must be established so that it does not exceed the design flap speed V_F chosen under §§ 25.335(e) and 25.345, for the corresponding flap positions and engine powers.

§ 25.1513 Minimum control speed.

The minimum control speed V_{MC} determined under § 25.149 must be established as an operating limitation.

§ 25.1515 Landing gear speeds.

(a) The established landing gear operating speed or speeds, V_{LO}, may not exceed the speed at which it is safe both to extend and to retract the landing gear, as determined under § 25.729 or by flight characteristics. If the extension speed is not the same as the retraction speed, the two speeds must be designated as $V_{LO(EXT)}$ and $V_{LO(RET)}$, respectively.

(b) The established landing gear extended speed V_{LE} may not exceed the speed at which it is safe to fly with the landing gear secured in the fully extended position, and that determined under § 25.729.

(Amdt. 25–38, Eff. 2/1/77)

[§ 25.1517 Rough air speed, V_{RA}.

[A rough air speed, V_{RA}, for use as the recommended turbulence penetration airspeed in § 25.1585(a)(8), must be established, which—

[(1) Is not greater than the design airspeed for maximum gust intensity, selected for V_B; and

[(2) Is not less than the minimum value of V_B specified in § 25.335(d); and

[(3) Is sufficiently less than V_{MO} to ensure that likely speed variation during rough air encounters will not cause the overspeed warning to operate too frequently. In the absence of a rational investigation substantiating the use of other values, V_{RA} must be less than V_{MO}—35 knots (TAS).]

[(Amdt. 25–86, Eff. 3/11/96)]

(a) *General.* The powerplant limitations prescribed in this section must be established so that they do not exceed the corresponding limits for which the engines or propellers are type certificated and do not exceed the values on which compliance with any other requirement of this part is based.

(b) *Reciprocating engine installations.* Operating limitations relating to the following must be established for reciprocating engine installations:

(1) Horsepower or torque, r.p.m., manifold pressure, and time at critical pressure altitude and sea level pressure altitude for—

(i) Maximum continuous power (relating to unsupercharged operation or to operation in each supercharge mode as applicable); and

(ii) Takeoff power (relating to unsupercharged operation or to operation in each supercharger mode as applicable).

(2) Fuel grade or specification.

(3) Cylinder head and oil temperatures.

(4) Any other parameter for which a limitation has been established as part of the engine type certificate except that a limitation need not be established for a parameter that cannot be exceeded during normal operation due to the design of the installation or to another established limitation.

(c) *Turbine engine installations.* Operating limitations relating to the following must be established for turbine engine installations:

(1) Horsepower, torque or thrust, r.p.m., gas temperature, and time for—

(i) Maximum continuous power or thrust (relating to augmented or unaugmented operation as applicable).

(ii) Takeoff power or thrust (relating to augmented or unaugmented operation as applicable).

(2) Fuel designation or specification.

(3) Any other parameter for which a limitation has been established as part of the engine type certificate except that a limitation need not be established for a parameter that cannot be exceeded during normal operation due to the

§ 25.1522 Auxiliary power unit limitations.

If an auxiliary power unit is installed in the airplane, limitations established for the auxiliary power unit, including categories of operation, must be specified as operating limitations for the airplane.

(Amdt. 25–46, Eff. 12/1/78); (Amdt. 25–72, Eff. 8/20/90)

§ 25.1523 Minimum flight crew.

The minimum flight crew must be established so that it is sufficient for safe operation, considering—

(a) The workload on individual crewmembers;

(b) The accessibility and ease of operation of necessary controls by the appropriate crewmember; and

(c) The kind of operation authorized under § 25.1525.

The criteria used in making the determinations required by this section are set forth in appendix D.

(Amdt. 25–3, Eff. 5/28/65)

§ 25.1525 Kinds of operation.

The kinds of operation to which the airplane is limited are established by the category in which it is eligible for certification and by the installed equipment.

§ 25.1527 Maximum operating altitude.

The maximum altitude up to which operation is allowed, as limited by flight, structural, powerplant, functional, or equipment characteristics, must be established.

§ 25.1529 Instructions for Continued Airworthiness.

The applicant must prepare Instructions for Continued Airworthiness in accordance with appendix H to this part that are acceptable to the Administrator. The instructions may be incomplete

Load factor limitations, not exceeding the positive limit load factors determined from the maneuvering diagram in § 25.333(b), must be established.

§ 25.1533 Additional operating limitations.

(a) Additional operating limitations must be established as follows:

(1) The maximum takeoff weights must be established as the weights at which compliance is shown with the applicable provisions of this part (including the takeoff climb provisions of § 25.121(a) through (c), for altitudes and ambient temperatures.

(2) The maximum landing weights must be established as the weights at which compliance is shown with the applicable provisions of this part (including the landing and approach climb provisions of §§ 25.119 and 25.121(d) for altitudes and ambient temperatures).

(3) The minimum takeoff distances must be established as the distances at which compliance is shown with the applicable provisions of this part (including the provisions of §§ 25.103 and 25.113, for weights, altitudes, temperatures, wind components, and runway gradients).

(b) The extremes for variable factors (such as altitude, temperature, wind, and runway gradients) are those at which compliance with the applicable provisions of this part is shown.

(Amdt. 25–38, Eff. 2/1/77); (Amdt. 25–72, Eff. 8/20/90)

MARKINGS AND PLACARDS

§ 25.1541 General.

(a) The airplane must contain—

(1) The specified markings and placards; and

(2) Any additional information, instrument markings, and placards required for the safe operation if there are unusual design, operating, or handling characteristics.

(b) Each marking and placard prescribed in paragraph (a) of this section—

the instrument, there must be means to maintain the correct alignment of the glass cover with the face of the dial; and

(b) Each instrument marking must be clearly visible to the appropriate crewmember.

(Amdt. 25–72, Eff. 8/20/90)

§ 25.1545 Airspeed limitation information.

The airspeed limitations required by § 25. 1583(a) must be easily read and understood by the flight crew.

§ 25.1547 Magnetic direction indicator.

(a) A placard meeting the requirements of this section must be installed on, or near, the magnetic direction indicator.

(b) The placard must show the calibration of the instrument in level flight with the engines operating.

(c) The placard must state whether the calibration was made with radio receivers on or off.

(d) Each calibration reading must be in terms of magnetic heading in not more than 45 degree increments.

§ 25.1549 Powerplant and auxiliary power unit instruments.

For each required powerplant and auxiliary power unit instrument, as appropriate to the type of instrument—

(a) Each maximum and, if applicable, minimum safe operating limit must be marked with a red radial or a red line;

(b) Each normal operating range must be marked with a green arc or green line, not extending beyond the maximum and minimum safe limits;

(c) Each takeoff and precautionary range must be marked with a yellow arc or a yellow line; and

(d) Each engine, auxiliary power unit, or propeller speed range that is restricted because of excessive vibration stresses must be marked with red arcs or red lines.

(Amdt. 25–40, Eff. 5/2/77)

If the unusable fuel supply for any tank exceeds one gallon, or five percent of the tank capacity, whichever is greater, a red arc must be marked on its indicator extending from the calibrated zero reading to the lowest reading obtainable in level flight.

§ 25.1555 Control markings.

(a) Each cockpit control, other than primary flight controls and controls whose function is obvious, must be plainly marked as to its function and method of operation.

(b) Each aerodynamic control must be marked under the requirements of §§ 25.677 and 25.699.

(c) For powerplant fuel controls—

(1) Each fuel tank selector control must be marked to indicate the position corresponding to each tank and to each existing cross feed position;

(2) If safe operation requires the use of any tanks in a specific sequence, that sequence must be marked on, or adjacent to, the selector for those tanks; and

(3) Each valve control for each engine must be marked to indicate the position corresponding to each engine controlled.

(d) For accessory, auxiliary, and emergency controls—

(1) Each emergency control (including each fuel jettisoning and fluid shutoff control) must be colored red; and

(2) Each visual indicator required by § 25.729(e) must be marked so that the pilot can determine at any time when the wheels are locked in either extreme position, if retractable landing gear is used.

§ 25.1557 Miscellaneous markings and placards.

(a) *Baggage and cargo compartments and ballast location.* Each baggage and cargo compartment, and each ballast location must have a placard stating any limitations on contents, including weight, that are necessary under the loading requirements. However, underseat compartments designed for the storage of carry-on articles weighing not more than

planes, the minimum fuel grade;

(iii) For turbine engine powered airplanes, the permissible fuel designations; and

(iv) For pressure fueling systems, the maximum permissible fueling supply pressure and the maximum permissible defueling pressure.

(2) Oil filler openings must be marked at or near the filler cover with the word "oil".

(3) Augmentation fluid filler openings must be marked at or near the filler cover to identify the required fluid.

(c) *Emergency exit placards.* Each emergency exit placard must meet the requirements of § 25.811.

(d) *Doors.* Each door that must be used in order to reach any required emergency exit must have a suitable placard stating that the door is to be latched in the open position during takeoff and landing.

(Amdt. 25–32, Eff. 5/1/72); (Amdt. 25–38, Eff. 2/1/77); (Amdt. 25–72, Eff. 8/20/90)

§ 25.1561 Safety equipment.

(a) Each safety equipment control to be operated by the crew in emergency, such as controls for automatic liferaft releases, must be plainly marked as to its method of operation.

(b) Each location, such as a locker or compartment, that carries any fire extinguishing, signaling, or other lifesaving equipment must be marked accordingly.

(c) Stowage provisions for required emergency equipment must be conspicuously marked to identify the contents and facilitate the easy removal of the equipment.

(d) Each liferaft must have obviously marked operating instructions.

(e) Approved survival equipment must be marked for identification and method of operation.

(Amdt. 25–46, Eff. 12/1/78)

§ 25.1563 Airspeed placard.

A placard showing the maximum airspeeds for flap extension for the takeoff, approach, and landing it must contain the following:

(1) Information required by §§ 25.1583 through 25.1587.

(2) Other information that is necessary for safe operation because of design, operating, or handling characteristics.

(3) Any limitation, procedure, or other information established as a condition of compliance with the applicable noise standards of part 36 of this chapter.

(b) *Approved information.* Each part of the manual listed in §§ 25.1583 through 25.1587, that is appropriate to the airplane, must be furnished, verified, and approved, and must be segregated, identified, and clearly distinguished from each unapproved part of that manual.

(c) [Reserved]

(d) Each Airplane Flight Manual must include a table of contents if the complexity of the manual indicates a need for it.

(Amdt. 25–42, Eff. 3/1/78); (Amdt. 25–72, Eff. 8/20/90)

§ 25.1583 Operating limitations.

(a) *Airspeed limitations.* The following airspeed limitations and any other airspeed limitations necessary for safe operation must be furnished:

(1) The maximum operating limit speed V_{MO}/M_{MO} and a statement that this speed limit may not be deliberately exceeded in any regime of flight (climb, cruise, or descent) unless a higher speed is authorized for flight test or pilot training.

(2) If an airspeed limitation is based upon compressibility effects, a statement to this effect and information as to any symptoms, the probable behavior of the airplane, and the recommended recovery procedures.

(3) The maneuvering speed V_A and a statement that full application of rudder and aileron controls, as well as maneuvers that involve angles of attack near the stall, should be confined to speeds below this value.

(4) The flap extended speed V_{FE} and the pertinent flap positions and engine powers.

(1) Limitations required by § 25.1521 and § 25.1522.

(2) Explanation of the limitations, when appropriate.

(3) Information necessary for marking the instruments required by §§ 25.1549 through 25.1553.

(c) *Weight and loading distribution.* The weight and center of gravity limits required by §§ 25.25 and 25.27 must be furnished in the Airplane Flight Manual. All of the following information must be presented either in the Airplane Flight Manual or in a separate weight and balance control and loading document which is incorporated by reference in the Airplane Flight Manual:

(1) The condition of the airplane and the items included in the empty weight as defined in accordance with § 25.29.

(2) Loading instructions necessary to ensure loading of the airplane within the weight and center of gravity limits, and to maintain the loading within these limits in flight.

(3) If certification for more than one center of gravity range is requested, the appropriate limitations, with regard to weight and loading procedures, for each separate center of gravity range.

(d) *Flight crew.* The number and functions of the minimum flight crew determined under § 25.1523 must be furnished.

(e) *Kinds of operation.* The kinds of operation approved under § 25.1525 must be furnished.

(f) *Altitudes.* The altitude established under § 25.1527.

(g) [Reserved]

(h) *Additional operating limitations.* The operating limitations established under § 25.1533 must be furnished.

(i) *Maneuvering flight load factors.* The positive maneuvering limit load factors for which the structure is proven, described in terms of accelerations, must be furnished.

(Amdt. 25–38, Eff. 2/1/77); (Amdt. 25–42, Eff. 3/1/78); (Amdt. 25–46, Eff. 12/1/78); (Amdt. 25–72, Eff. 8/20/90) trim, operation of the remaining engines, and operation of flaps);

(2) Stopping the rotation of propellers in flight;

(3) Restarting turbine engines in flight (including the effects of altitude);

(4) Fire, decompression, and similar emergencies;

(5) Ditching (including the procedures based on the requirements of §§ 25.801, 25.807(d), 25.1411, and 25.1415 (a) through (e));

(6) Use of ice protection equipment;

(7) Use of fuel jettisoning equipment, including any operating precautions relevant to the use of the system;

(8) Operation in turbulence for turbine powered airplanes (including recommended turbulence penetration airspeeds, flight peculiarities, and special control instructions);

(9) Restoring a deployed thrust reverser intended for ground operation only to the forward thrust position in flight or continuing flight and landing with the thrust reverser in any position except forward thrust; and

(10) Disconnecting the battery from its charging source, if compliance is shown with § 25.1353(c)(6)(ii) or (c)(6)(iii).

(b) Information identifying each operating condition in which the fuel system independence prescribed in § 25.953 is necessary for safety must be furnished, together with instructions for placing the fuel system in a configuration used to show compliance with that section.

(c) The buffet onset envelopes determined under § 25.251 must be furnished. The buffet onset envelopes presented may reflect the center of gravity at which the airplane is normally loaded during cruise if corrections for the effect of different center of gravity locations are furnished.

§ 25.1587 Performance information.

(a) Each Airplane Flight Manual must contain information to permit conversion of the indicated temperature to free air temperature if other than a free air temperature indicator is used to comply with the requirements of § 25.1303(a)(1).

(b) Each Airplane Flight Manual must contain the performance information computed under the applicable provisions of this part for the weights, altitudes, temperatures, wind components, and runway gradients, as applicable, within the operational limits of the airplane, and must contain the following:

(1) The conditions under which the performance information was obtained, including the speeds associated with the performance information.

(2) V_S determined in accordance with § 25.103.

(3) The following performance information (determined by extrapolation and computed for the range of weights between the maximum landing and maximum takeoff weights):

(i) Climb in the landing configuration.

(ii) Climb in the approach configuration.

(iii) Landing distance.

(4) Procedures established under § 25.101(f), (g), and (h) that are related to the limitations and information required by § 25.1533 and by this paragraph. These procedures must be in the form of guidance material, including any relevant limitations or information.

(5) An explanation of significant or unusual flight or ground handling characteristics of the airplane.

(Amdt. 25–23, Eff. 5/8/70); (Amdt. 25–42, Eff. 3/1/78); (Amdt. 25–72, Eff. 8/20/90)